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(71) Applicant: TOSOH SMD, INC. [US/US]; 3515 Grove City Road, Grove City, OH 43123 (US).

(72) Inventors: WICKERSHAM, Charles, E. ; 571 Arden Road, Columbus, OH 43214 (US). MANRING, William, A. ; 7910 Beecher Road, Pataskala, OH 45062 (US).

(74) Agents: PEACOCK, Bruce, E. et al.; Biebel & French, 2500 Kettering Tower, Dayton, OH 45423 (US).

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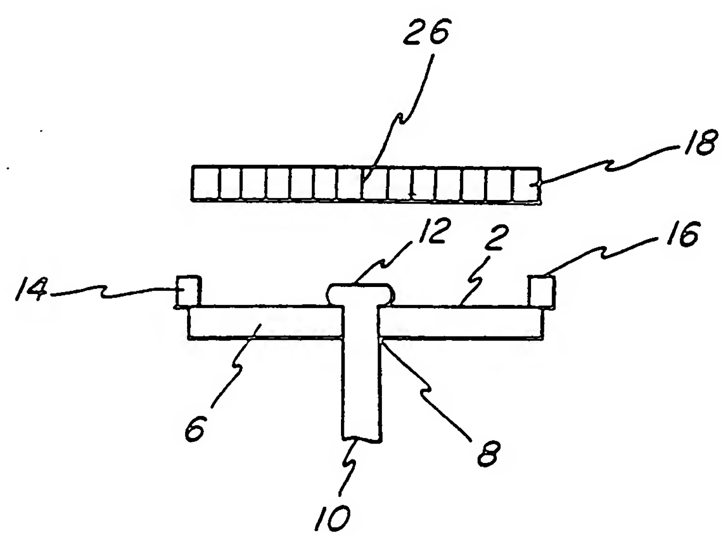

(57) Abstract

Improved sputter targets (18) adapted especially for providing coating on the annular portions (2) of compact discs (6) are disclosed along with methods of sputter coating use thereof and methods of manufacture of the specifically designed targets. The crystallographic orientation (26) of the target materials is provided so that the preferred angle of atomic emission from the target (18) is arranged substantially perpendicular to the surface of the compact disc substrate (6) to be coated. Such specific crystallographic orientations (26) may be provided by uniaxially compressing aluminum billets.

IMPROVED SPUTTER TARGET FOR COATING COMPACT DISCS, METHODS OF USE THEREOF, AND METHODS OF MANUFACTURE OF THE TARGETS

Field of the Invention

The present invention pertains to a sputter target adapted for use in cathodic sputter systems for applying a metallic coating onto an annular region of a substrate such as a compact disc. Methods of using such targets in sputter coating processes are also within the purview of the invention.

Background of the Invention

Sputtering systems are conventionally used for depositing thin films of materials upon substrates. These systems involve gas ion bombardment of a target cathode having a face formed of a material that is to be deposited as a thin film or coating upon the substrate.

The target forms part of a cathode assembly which together with an anode is disposed within an evacuable chamber that contains an inert gas, such as Argon. A high voltage field is applied across the cathode and anode to thereby ionize the gas particles. Positively charged gas ions are attracted to the cathode and upon impingement with the target surface dislodge the target material. The thus dislodged cathode target materials traverse the evacuated chamber and deposit as a thin film on the desired substrate that is usually located proximate the anode.

In addition to the use of an electric field, increased sputtering rates may be achieved by the concurrent use of an arch-shaped magnetic field that is superimposed over the electrical field and formed in a closed loop configuration over the surface of the sputter target. These methods are known as magnetron sputtering methods. The arch-shaped magnetic field traps electrons in an annular region adjacent to the target surface thereby increasing the number of electron-gas atom collisions in the area to produce an increase in the number of positively charged gas ions in the region that strike the target to dislodge the target material. Accordingly, the target material becomes eroded (i.e., consumed for subsequent deposition on the substrate) in a generally annular section of the target face known as the target race-way.

Often, cathodic sputtering is used to coat thin semiconductor-elements, such as silicon wafers, with critically thin conductive films. In these cases, as well as in many others, the desire is to provide a uniform thin coating on the semiconductor element. In an article entitled, "Crystallographic Target Effects in Magnetron Sputtering Systems", Jour. Vacuum Science & Technology, A5(4) July/August 1987, Dr. Wickersham built upon earlier work by Wehner et al[1], in reporting that the uniformity of

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[1]G.K. Wehner, J. Appl. Phys. 26, 1056 (1955) and G.K. Wehner, Phys. Rev. 102, 690 (1956).

sputtered coatings from strongly textured polycrystalline sputter targets can be increased by controlling the target crystallographic orientation. This desire for uniformity resulted in production of targets having controlled crystallographic orientation so as to result in the application of a uniform coating over the substrate with the thickest deposit being positioned in the center of the substrate with the thickness decreasing in the radial direction.

Presently, compact disc (CD) manufacture has become an increasingly significant sputter coating area in which a thin aluminum film on the disc substrate is provided to store the desired audio information. However, in contrast to the desire for uniformity in coating over the entire disc substrate, this operation requires that an annulus of aluminum, such as that shown by annular region 2 of a typical compact disc 4 be provided over the substrate 6, such as a mylar plastic or the like (see Fig. 1). To this end, sputter systems, such as those diagrammatically shown in Fig. 2 have been used wherein the substrate 6 to be sputtered comprises a control aperture 8 that is secured in the sputter system vacuum chamber by means of a spindle 10 having removable shroud 12 or the like and mask portions 14, 16. Target 18 then uniformly sputters over the substrate 6 with the shroud 12 and mask portions 14, 16 of the assembly shielding the substrate 6 so that sputter coating on the desired annular

portion 2 of the substrate occurs to result in a CD 4, such as shown in Fig. 1.

It is apparent that in such traditional CD sputtering systems, uniform emission of the coating materials from the target to the disc-mask surface actually results in wastage of the sputtered materials as they contact portions of the mask 14, 16 and shroud 12 overlying the compact disc. This sharply contrasts with the desire to provide uniform coatings on silicon wafers and the like.

Accordingly, in order to increase the number of CDs that can be coated per sputter target, it is desired to provide a target material that is adapted preferentially to emit the desired coating material to the annular region of the substrate where the coating is desired. Additionally, by providing for such controlled target emissions, collection efficiency is increased.

Detailed Description of the Invention

In accordance with the invention, it has been surprisingly found that specific crystallographic orientation of the close packed direction of the metallic lattices of the target metal is effective in providing a non-uniform emission that actually preferentially coats the annular region of the CD substrate in a cathodic sputter system. Simply speaking, the close packed direction of the target is oriented, as shall be explained hereinafter, in such manner that it is aligned

substantially perpendicular (i.e., ±15° from 90°) with respect to the plane of the substrate surface to be coated.

The invention will now be further described in conjunction with the appended drawing figures.

Drawings

In the drawings:

Fig. 1 is a schematic illustration of a typical compact disc;

Fig. 2 is a schematic showing target and substrate disposition in commercially available CD sputtering systems;

Fig. 3 is a schematic illustration of a face centered cube atomic lattice disposition;

Fig. 4 is a schematic illustration showing the normal emission envelope for a target 18 composed of an amorphous sintered powder having a b/a of 1;

Fig. 5 is a schematic illustration showing the normal emission envelope for a target 18 having a b/a of ≈3 and exhibiting a FCC lattice structure;

Fig. 6 is a schematic illustration of a target, in accordance with the invention, mounted in a conventional, commercially available CD sputtering system;

Fig. 7 is a schematic illustration of a method for obtaining metal having the preferred crystallographic orientation for use in the invention;

Fig. 8 is a graphic depiction of data resulting from a Monte Carlo computer simulation indicating coating thickness per substrate location for various tested targets; and

Fig. 9 is another graphic depiction of data from a Monte Carlo computer simulation of the type described in conjunction with Fig. 8.

It is known in the art that many metals, such as Al, Au, Pt, Cu, Ni, Ag and Pd, and alloys containing those metals, exhibit atomic lattice arrangements known as face centered cubes (FCC). With attention to Fig. 3, such a FCC atomic lattice is shown having atoms, such as Al atoms, 20 disposed at all cube face intersections and an atom (see 20a) disposed in the center of each face.

The close packed arrangement is defined as the direction, in the lattice, in which the atoms are disposed in their most tightly packed disposition. It is to be remembered that the atoms may be so arranged, whether a pure element is provided, or, as in most cases, alloys containing such FCC metals are used. Accordingly, as used herein, FCC metals shall mean pure elemental metal and metal alloy forms that exhibit such face centered cube (FCC) disposition of the atoms (in the pure elemental form) or atoms or ions (existing in the alloy).

As an aid in locating atoms in the lattice and to define the close packed direction, three-dimensional x, y, z coordinates are used as shown in Fig. 3. For FCC type lattices, the close packed direction can be defined

as a vector corresponding to the reciprocal of 1x, 1y, and 0 units in the z direction. Hence, for a FCC lattice, the close packed direction is denoted 110.

In contrast to FCC arrangements, certain materials, such as Fe, Ta, Ba, Ce, Mo, W, and V, exhibit body centered cubic structure (BCC) wherein in addition to location of atoms or metallic ions at intersections of the cube faces an atom or ion is located at the center of the cube without atom or ion disposition in the center of each of the cube faces. In these BCC lattice systems, the close packed direction is denoted 111. In the sputter coating art, it is known that the ejection of sputtered atoms occurs preferentially along (i.e., in line with) close packed directions in the target.

In Fig. 4, a directed emission vector E is shown for an amorphous sintered powder material. Here, vector E is parallel to the target 18 surface normal or, stated differently, is perpendicular to the target face plane. An emission envelope 24 is present having a major radius b and a minor radius a of equal dimension. Thus the envelope in such systems is a circle. It should be noted here that the ratio b/a is a function of the particular target material used. In sintered powders, the b/a ratio is known as being 1. Conversely, in cast or worked metals, the b/a dimension is greater than 1, usually 3 and provides an elliptically-shaped emissions envelope (see Fig. 5).

Turning back again to Fig. 4, the probability of atomic ejection from the target during sputtering at the angle 0 shown in the figure is equal to a constant times the cosine θ.

$$p(\theta) = K \cos(\theta)$$

This is known as the normal cosine emission formula and is well known to those skilled in the field of sputter coating.

Fig. 5 illustrates a theoretical emission envelope for a cast or worked metal. Here, the b/a ratio is greater than 1, normally 3, and the envelope 24 is therefore in the shape of an ellipse. This is the type of b/a emission envelope with which the present invention is concerned in light of the fact that the preferred coating material for a CD substrate is to be a cast or worked metal, specifically aluminum. The lines 26 of target 18 in Fig. 3 are indicative of the crystallographic orientation of the close packed direction for the target material. That is, the 110 direction is represented by lines 26. In accord with well known theory then, preferred emission from the target 18, in Fig. 5, will occur along vector E that is set from the target normal N at an angle λ. The probability of emission at an 0 from E is defined in accord with the known directed cosine emission equation

$$P(\theta) = K \cos(\theta)/[(b/a)^2 \sin^2(\theta) + \cos^2(\theta)]$$

The present inventors have surprisingly found that by varying the angle λ in systems, such as shown in Fig. 5, optimal target ejection for CD substrates can be found.

As has previously been alluded to, a conventional CD sputtering system is shown in Fig. 2. Details of cathode sputtering systems in general are well known and need not be repeated herein. One such system is shown in U.S. Patent 4,478,701 (Welch), the disclosure of which is incorporated by reference herein to the extent necessary to complete this disclosure.

The commercially available systems now in use for cathode sputtering of a CD all comprise a target 18 provided in parallel disposition to CD substrate 6. It is to be noted that the CD substrates 6 are provided on a "jukebox" type feed system wherein successive CDs are rapidly fed, sputtered, and then removed from the vacuum chamber. The CD is provided with central aperture 8 inserted onto feed system spindle 10 with shroud 12 connected to the spindle and with appropriate mask members 14, 16 adapted to expose annulus portion 2 to sputter coating. During actual sputtering, the CD is held stationary with respect to target 18.

We have found that CD sputtering is significantly enhanced if the close packed direction of the target material lattice(s) is provided such that λ in Fig. 5 is zero or substantially zero (±15°). More importantly, the preferred emission vector E for the target is such that E will be substantially perpendicular

with respect to the surface plane of the CD substrate provided in the vacuum chamber. A diagrammatic illustration of a target 18 in accordance with the invention for insertion into the system of Fig. 2 is shown in Fig. 6. After insertion, target 18 (Fig. 6) has its close packed direction 26 arranged so that λ is zero or substantially zero (±15°).

The orientation of the close packed direction in the target therefore determines the uniformity of the deposit over the CD. This orientation can be controlled by solidification of the target material from the melt using directional solidification techniques, or more preferably by working the metal after casting. With respect to the latter method, it is known that rolling aluminum metal and then annealing the rolled aluminum produces a 110 direction that is 45° from the surface normal and is hence unacceptable for CD sputtering in the known conventional systems wherein target and CD substrate are parallel to each other. Uniaxial forging of the aluminum produces a 110 direction which is parallel to the surface normal and is therefore preferred for CD sputtering systems of the type shown in Fig. 6. Extrusion of aluminum produces a 110 direction that is 35° from the surface normal.

The aluminum working method comprises subjecting billets to a uniaxially imposed compressive force of about 400 to 600 tons while heat treating the compressed billets to a temperature in the range of about 500-800°F. The

preferred method subjects the billet to a force of about 500 tons while heating at about 650-750°F. Compression is undertaken until the resulting billet is about one-half of its original length. The billet is then cooled and machined into the specific configuration required by the end-user. The following preferred method steps are undertaken:

1. Use 5.5" diameter, 1100 commercial aluminum stock;
2. Saw billets from the stock of 3.25" length (± 0.125") long;
3. Insert billets into a flat die set into a 2000 ton press;
4. Vertically press the billet while applying heat;
5. Press in the die set to 1.625" length;
6. Quench with water;
7. Machine to desired customer target contour.

As mentioned above, controlled metal solidification techniques may also be employed to provide the desired <110> orientation. One such technique, although clearly not preferred, is described in conjunction with Fig. 7. In this figure, molten metal 30 is poured into metal mold 32. Initially, mold 32 acts as a heat sink and a thin layer of fine grain growth metal 34 is formed around areas of contact of the molten metal with the mold surfaces. This thin layer may be on the order of about .030 - .040" in thickness. Disposed in the middle

of mold 32 is a section of the molten metal characterized by large crystal growth areas exhibited equiaxial crystal growth 36. Intermediate areas 36 and 34 however is an area 38 of the molten metal wherein uniaxial growth of the 110 direction occurs. After cooling and solidification, this portion of the metal can be isolated and used to provide the desired target having a λ of substantially 0.

It should also be noted in conjunction with the embodiment shown in Fig. 7 that heat may be extracted from the mold 32 in such direction that crystal growth in the 110 direction is promoted. For example, in normal solidification procedures, growth along the 100 direction predominates. Heat could be extracted from the mold at a 45° angle from this orientation to promote 110 disposition.

Targets for use in sputtering coating processes for preferentially distributing coating material around an annular region of a substrate adapted for compact disc usage made in accordance with the above methods therefor comprise an FCC metal material composed of atoms (or ions) arranged in the form of a lattice. The target includes a surface from which the coating material is to be emitted with the lattice arrangement being such that the most tightly spaced atoms of the lattice exhibit directional vectors corresponding to a close packed direction oriented at an angle of substantially 0 with respect to a vector extending normal to the target surface. More preferably, such lattice arrangement exists in the form of a face cube

center lattice disposition wherein atomic or ionic members of the lattice are selected from the group consisting of aluminum, gold, and platinum atoms. Most preferably, the atoms consist essentially of aluminum atoms or ions.

When finished, the desired target will have a thickness, as measured along the line parallel to the close packed direction of the lattice, of about ½ to 3 inches. These targets will exhibit an envelope of predicted emissions defined by a major radius b and a minor radius a, wherein b/a is greater than 1 and is preferably equal to 3.

Generally speaking, methods of manufacturing sputter targets of the type hereinabove described which exhibit a specifically oriented crystal lattice disposition designed to preferentially emit materials from the target surface to coat an annular region on a desired substrate, will comprise forming a billet of the required metal material and either cutting the billet to the required length or forming the billet to that length. The billet or portion of the billet is then uniaxially pressed to about one-half of its original length configuration. The billet is then machined into the desired end use configuration. Preferably, prior to machining, the billet is heated and the heating and pressing steps are conducted simultaneously in the preferred methods.

Examples

In order to demonstrate the efficacy of the compact disc cathode sputtering methods and specific crystallographically oriented targets used in the methods, Monte Carlo computer simulations were performed using various target crystallographic textures for test aluminum targets for simulated sputtering in computer models of commercially available compact disc cathode sputtering systems.

Results generated are shown in Table 1.

Table I

Angle of closed pack direction	b/a	%collected[2]	Avg. Dep. Rate[3]	% Uniformity[4]
0	3	44.5	5100	9.1
35	3	33.3	3892	15.6
45	3	27.2	3818	12.5
0	1	32.9	3171	15.3
actual non-simulation run	-		4010	8.2

Additionally, Monte Carlo simulations were performed in conjunction with a model compact disc cathodic sputtering system using the model b/a and target parameters and model target-substrate separation parameters indicated in Figs. 8 and 9. These figures, like Table I, indicate the desirability of sputter coating compact discs in test systems where the target b/a ratio

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[2]Equal to the percentage of total sputtered atoms located at a specific portion of the Al coated annulus of the C.D.

[3]Number of atoms per unit time that contact the same portion of the annulus as used in the calculation of footnote 2 (% collected) data.

[4]Uniformity measured at the same annulus location as per footnotes 2 and 3 with comparison made between different compact discs measured at those same locations (Tmax-Tmin)/(Tmax + Tmin)

is 3 and the crystallographic structure of the target is such as to have a surface emission angle λ of substantially 0. As is indicated by Figs. 8 and 9 and Table I, more aluminum is expected to deposit in the desired annulus area of the compact disc substrate, signifying that for any given target made with the desired crystallographic orientation, more compact discs can be coated than if the crystallographic target orientations of the <110> direction are not perpendicular to the target surface.

As shown in the data reported in Table I and in Figs. 8 and 9, the orientation of the 110 direction in the target determines the uniformity characteristics of the deposit. With respect to the data, it indicates that as the 110 direction in the target moves from 45° away from the surface normal (typical rolling texture) to being parallel to the surface normal (forged billet texture), the thickness of the sputtered deposit over the desired coating area increases. This increase means that the number of CDs that can be coated with the sputtering target increases because the material is being deposited more efficiently. Also, the higher coating rate means that the rate at which discs can be coated can also be increased.

The results for targets with directed emission (specifically oriented 110 directions) (see Table) are found to be 30% higher in deposition rate, 30% more discs coated per target and film uniformity improves from 15.6%

to 9.1%. This means that by using the directed sputtering target, productivity will increase by 33% over present CD sputtering targets in use.

While the invention has been described hereinabove with respect to specific embodiments of same, such are not intended to limit the scope of the invention. The invention is intended to cover any equivalents, modifications, etc., and is not to be limited solely by the scope of the appended claims.

1. In a system for sputter coating material emitted from a sputter target onto an annular region of a compact disc substrate surface, a sputtering method comprising: providing said target with coating material thereon arranged on said target in a multiplicity of atomic or ionic lattices formed with the most tightly spaced atoms or ions of each said lattice exhibiting directional vectors corresponding to a close packed direction disposed perpendicularly with respect to said substrate surface, bombarding said target with ions in said sputtering system to dislodge said coating material from said target and to coat said annular region of said compact disc substrate surface while minimizing the amount of coating material deposited onto other areas of said substrate.

2. Method as recited in claim 1 wherein said target exhibits an envelope of predicted emissions defined by a major radius b and a minor radius a wherein b/a is greater than about 1.

3. Method as recited in claim 2 wherein b/a is equal to about 3.

4. A method for sputtering coating material emitted from a sputter target onto an annular region of a compact disc substrate surface, wherein said coating material comprises a face centered cube (FCC) metal lattice distribution of atoms or ions, the method comprising orienting said lattice distribution so that the atoms or ions in their most tightly spaced dispositions called the close packed direction are disposed in said target substantially perpendicularly to a plane defined by said substrate said (FCC) metal comprising a member selected from the group consisting of aluminum, gold, platinum, copper, nickel, silver and palladium and alloys thereof.

5. A method as recited in claim 4 wherein (FCC) metal is aluminum or aluminum containing alloy.

6. Sputter target for use in a sputter coating process for preferentially distributing coating material around an annular region of a substrate adapted for compact disc usage, said target comprising a face centered cube (FCC) metal material or alloy composed of atoms or ions arranged in the form of a lattice, said target comprising a surface from which said coating material is to be emitted, said lattice arrangement being such that the most tightly spaced atoms or ions of said lattice exhibit directional vectors corresponding to a close packed direction, said close packed direction being oriented in said target material at an angle of

substantially zero with respect to a vector extending normal to said target surface.

7. A target as recited in claim 6 wherein said FCC metal comprises a member selected from the group consisting of aluminum, gold, platinum, copper, nickel, silver, and palladium and alloys thereof.

8. A target as recited in claim 7 wherein said FCC metal comprises a member selected from the group consisting of aluminum, gold and platinum and alloys thereof.

9. A target as recited in claim 8 wherein said FCC metal consists essentially of aluminum.

10. A target as recited in claim 9 having a thickness, as measured along a line parallel to said close packed direction of about ¼ inch to about 3 inches.

11. A target as recited in claim 6 exhibiting an envelope of predicted emissions, said envelope defined by a major radius b and a minor radius a wherein b/a is greater than 1.

12. A target as recited in claim 11 wherein b/a is equal to about 3.

13. Method of manufacturing a sputter target including a face cube center (FCC) metal exhibiting a specifically oriented crystal lattice disposition to preferentially emit materials from its surface to coat an annular region on a substrate, which substrate is adapted for usage as a compact disc, said method comprising forming a billet from said FCC metal, uniaxially pressing said billet, and machining said pressed billet to a desired configuration for use as said target.

14. Method as recited in claim 13 further comprising heating said billet prior to said machining.

15. Method as recited in claim 13 wherein said heating and said pressing are conducted simultaneously.

16. Method as recited in claim 13 wherein said heating comprises heating said billet to a temperature of about 500 to 800°F.

17. Method as recited in claim 13 comprising uniaxially pressing said billet under a force of about 400 to 600 tons until said billet comprises a height of above half of its original height prior to aid pressing.

18. Method as recited in claim 13 wherein said FCC metal comprises a member selected from the group consisting of aluminum, gold, platinum, copper, nickel, silver and palladium and alloys thereof.

19. Method as recited in claim 18 wherein said FCC metal comprises aluminum or alloy containing aluminum.

FIG-1

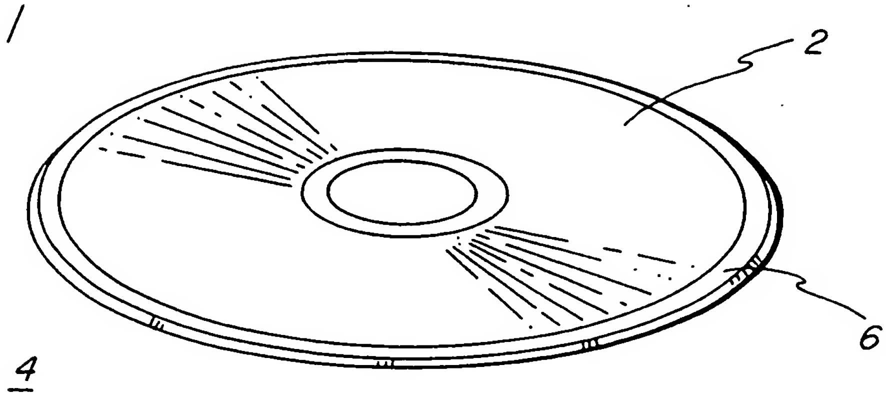


FIG-7

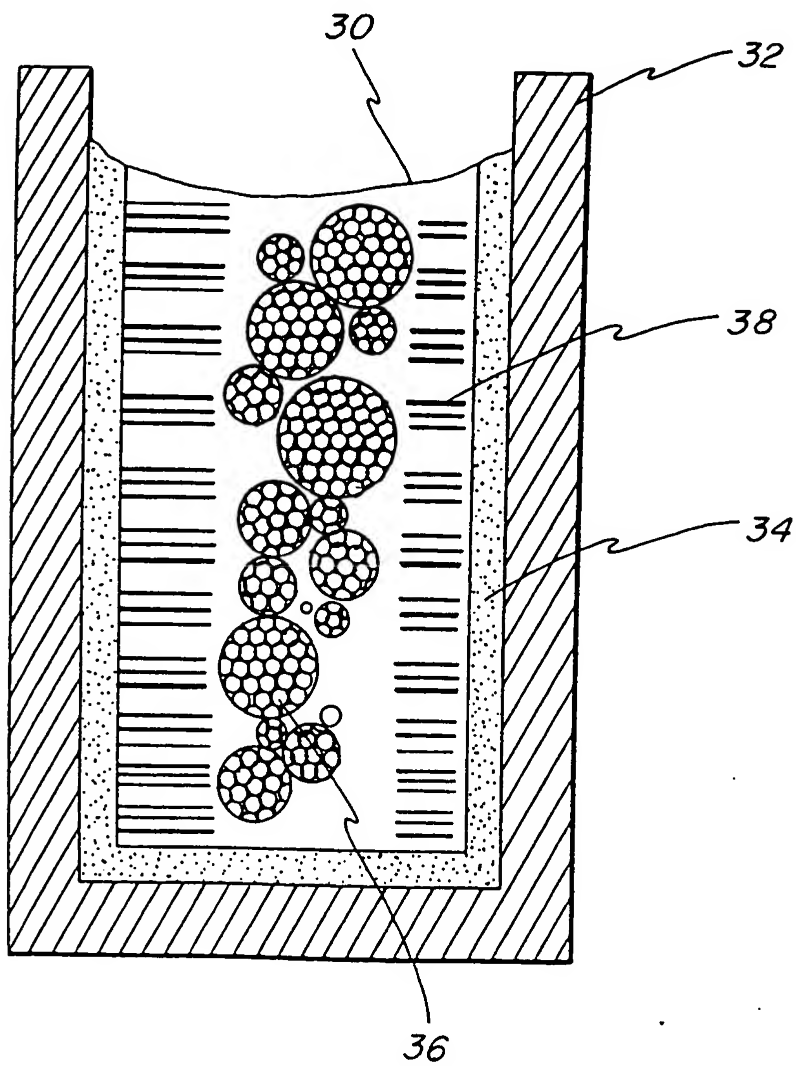


FIG-2

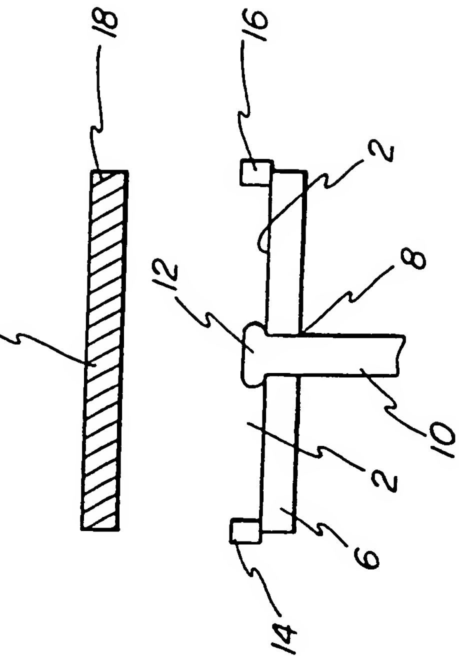


FIG-6

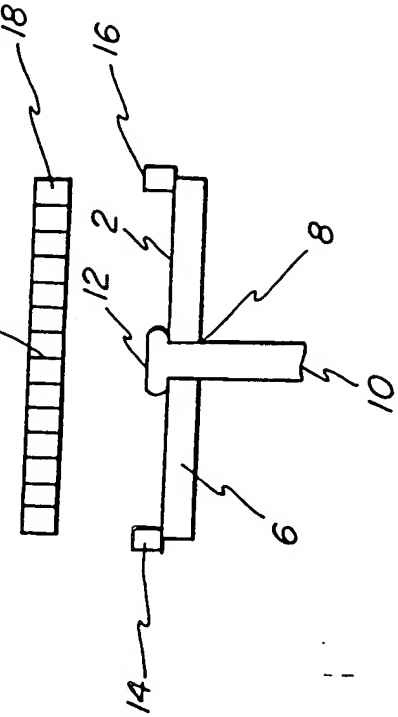


FIG-5

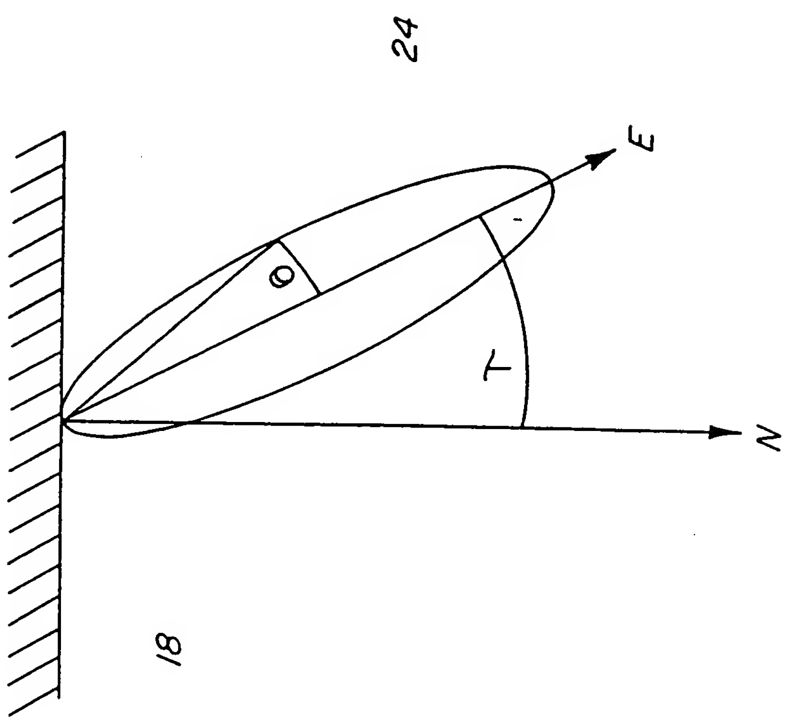


FIG-3

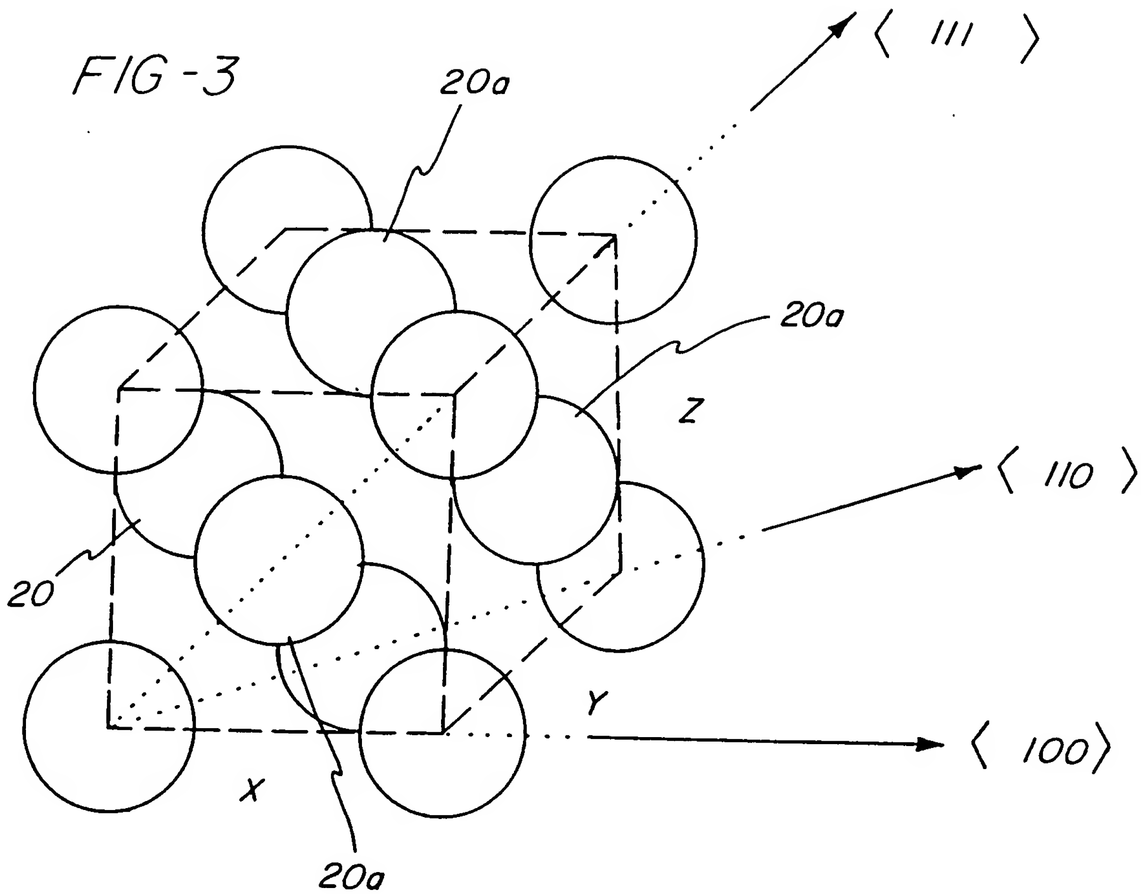
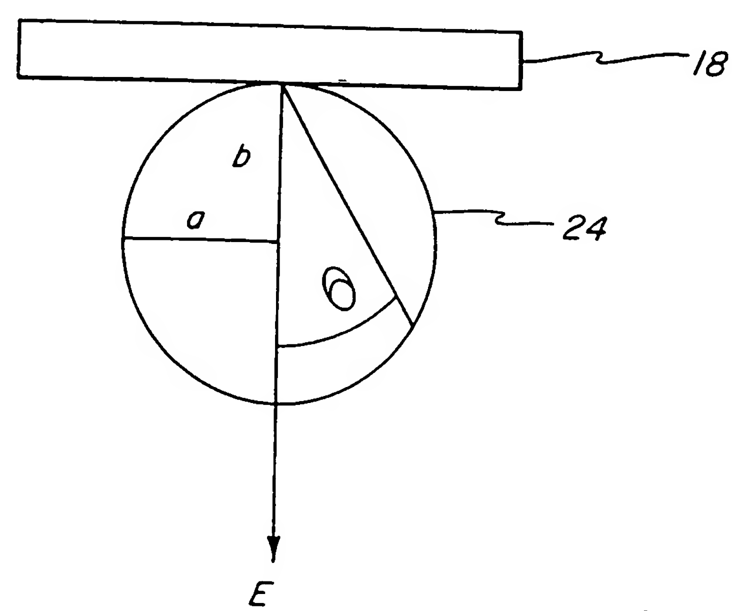


FIG-4



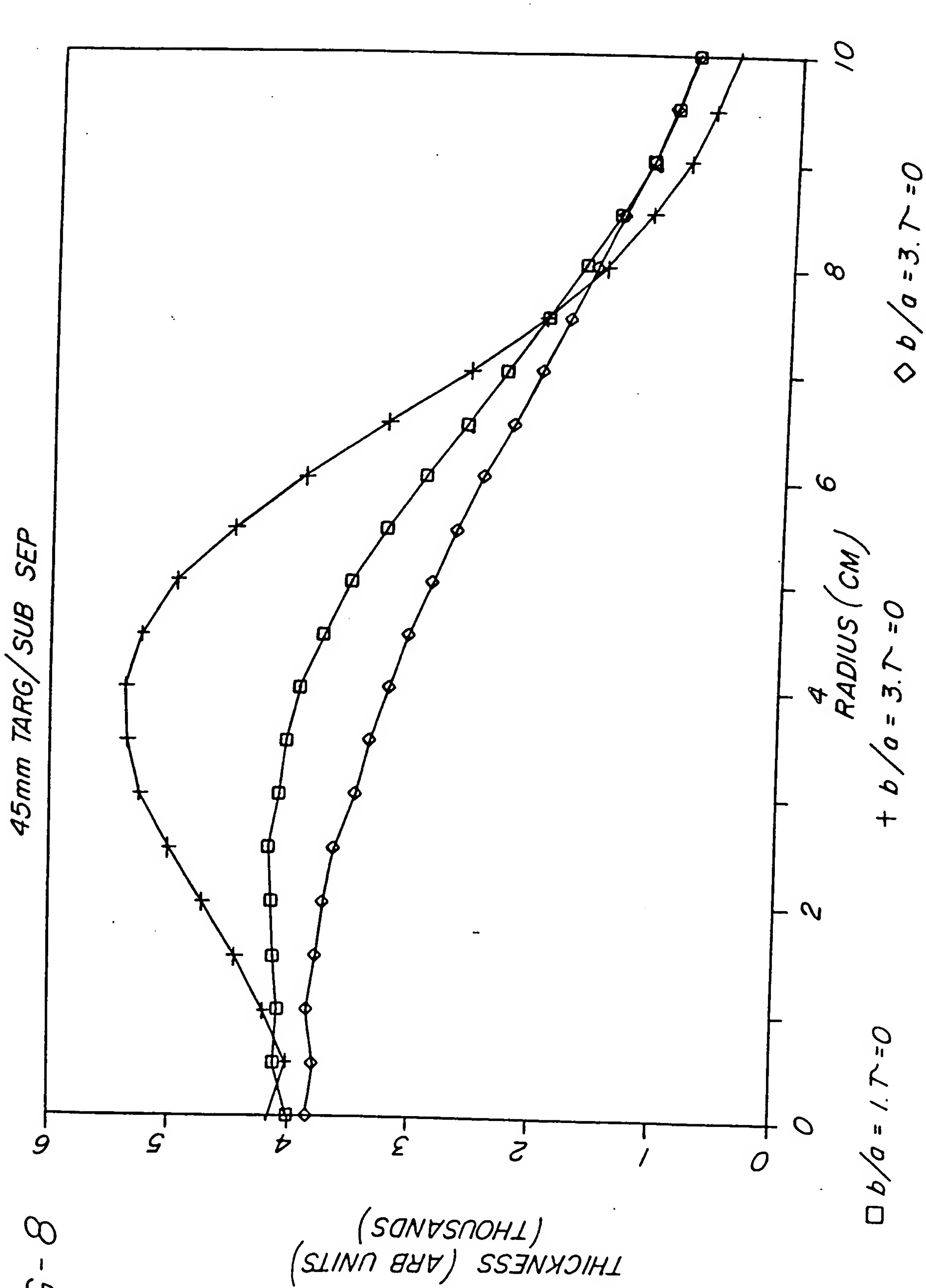

45mm TARG/SUB SEP
THICKNESS (ARB UNITS)
(THOUSANDS)
RADIUS (CM)
0
2
4
6
8
10
0
1
2
3
4
5
6
□ b/a = 1. T = 0
+ b/a = 3. T = 0
◇ b/a = 3. T = 0

FIG-8

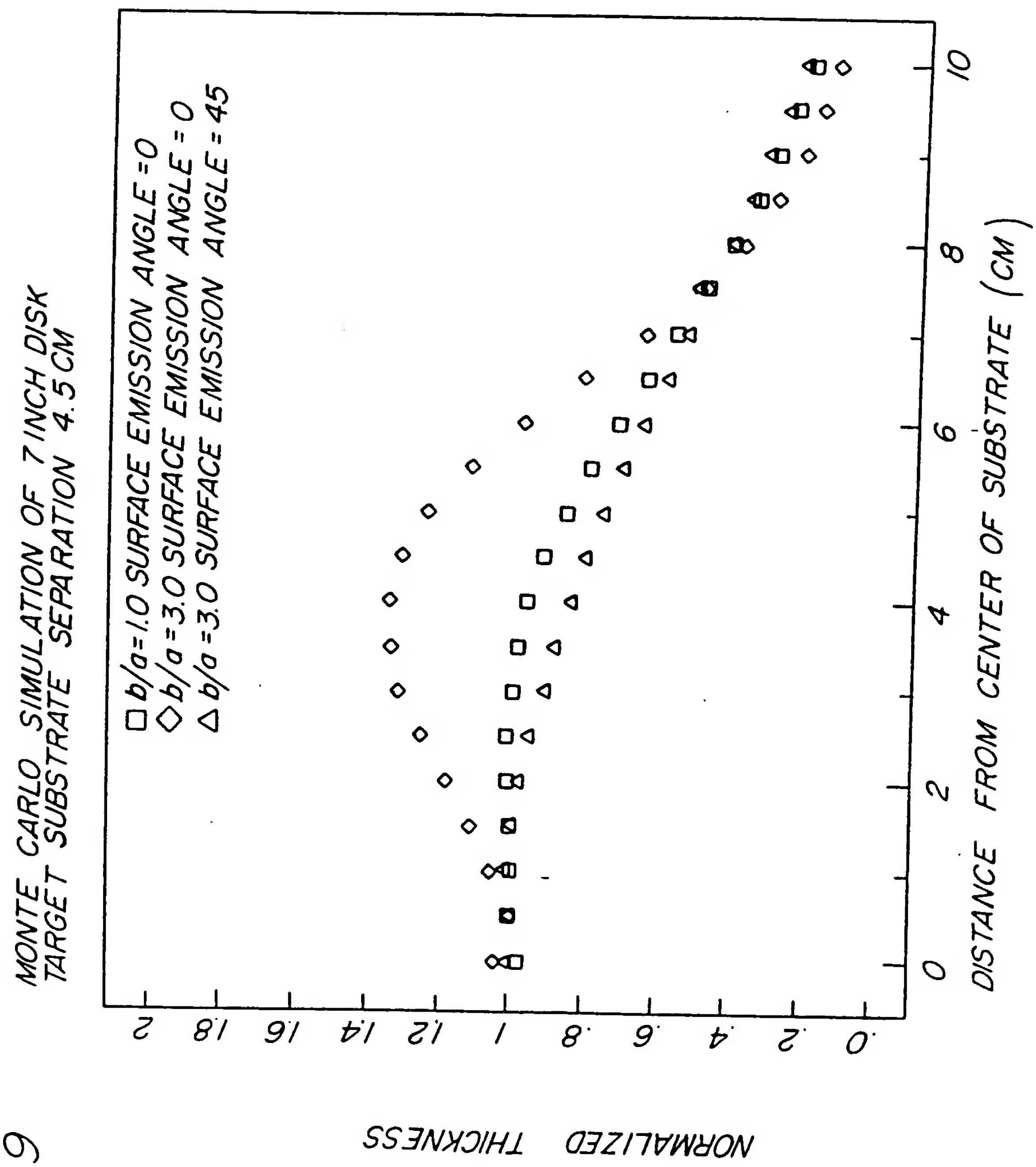

MONTE CARLO SIMULATION OF 7 INCH DISK
TARGET SUBSTRATE SEPARATION 4.5 CM
b/a=1.0 SURFACE EMISSION ANGLE =0
b/a=3.0 SURFACE EMISSION ANGLE = 0
b/a=3.0 SURFACE EMISSION ANGLE = 45
0
.2
.4
.6
.8
1
1.2
1.4
1.6
1.8
2
0
2
4
6
8
10
DISTANCE FROM CENTER OF SUBSTRATE (CM)
NORMALIZED THICKNESS

FIG-9

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/03989

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): C23C 14/34
U.S.Cl.: 204/192.15, 192.2, 298.13

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S.	204/192.15, 192.2, 298.13

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No [13]
X	C. E. Wickersham, Jr., "Crystallographic Target Effects in Magnetron Sputtering", Jul/ Aug. 1987, pp 1755-1758, J. Vac. Sci. Technol A 5(4). See entire document.	1-18
X	G. K. Wehner, "Controlled Sputtering of Metals by Low-Energy Hg Ions", May 1, 1956, pp 690-704, Physical Review, Vol. 102, No. 3 See entire document.	1-18
X	G. K. Wehner, "Sputtering of Metal Single Crystals by Ion Bonbardment", Aug. 1955, pp. 1056-1057, Journal of Applied Physics, Vol. 26, No. 8. See entire document.	1-18
X	J. L. Vossen et al., "Thin Film Process", Academic Press, New York, 1978, p. 14-18, See Table I-II.	1-18

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
05 August 1991	23 AUG 1991
International Searching Authority	**Signature of Authorized Officer**
ISA/US	N. Nguyen